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Cycling Athlete Performance: Analysis of Muscle Oxygen Saturation through Moxy Measurement

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Abstract

This study was aimed at conducting an analysis related to the performance of cyclists, namely the analysis of oxygen saturation in the muscles using muscle oxygen monitoring. This study used a single-subject design. Respondents of this study were road bike athletes preparing for multi-event competitions in West Java province. The measured data were related to oxygen saturation as measured by Moxy (Muscle Oxygen Monitoring), the tool used to examine how well our muscles use oxygen. The instruments included a smartwatch as an additional data collection tool and the Elevate Heart Rate sensor on the watch to record heart rate. The results found that the respondent muscle oxygen saturation was in the fairly good category for the female because the average result fell in the range of 70–80%, not much different from the starting point of the test. The analysis showed that there was a positive correlation between SmO2 and THb, where SmO2 gave a contribution of 61%. The result of this analysis is expected to be used as an evaluation for coaches in preparing athlete training programs.

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INTRODUCTION

Aerobic and anaerobic powers are required for competitive cycling (Tanaka et al., 1993). The ability to generate a relatively high power output for a brief time during the mass start, steep climbing, and race finish is necessary for road and off-road bicycle racing (Faria et al., 2005). Maximum oxygen consumption (VO2max) is one of the best determinants of success in competitive road cycling (Burke, 1980; Burke et al., 1977). Horowitz et al. (1994) compared two groups of cyclists with significantly different gross efficiencies but similar mean performance VO2 (4.46 vs. 4.48 L*min-1). In a one-hour cycling performance test, they found that the group with the higher efficiency had a significantly better average power output (342 W versus 315 W) (Horowitz et al., 1994). Sprint interval training (SIT) is a type of training that helps cyclists perform better. It consists of short sprints of 20-30 seconds, with long recovery periods (≥ 2 minutes) which has been shown to increase the strength and endurance of cyclists (Laursen et al., 2002). Even though the time spent at >90% VO2max during a SIT session is low (typically 0 -60 seconds in trained cyclists for the entire training session), muscle O2 requirements remain high due to the high number of sprints, with low levels of muscle oxygenation (Buchheit et al., 2012).

Although SIT training has been shown to improve exercise performance and some measures of muscle metabolism, the majority of studies have focused on how it alters sports performance (Gibala & McGee, 2008). There has not been much study on power measurement as compared to professional riding, despite the fact that cycling power meters have been sold for over 25 years (Vogt et al., 2007). However, the evolution of modern sensor technology has resulted in wireless and mini near infrared spectroscopy devices that can be used for applications in the field and during real racing. This technology can provide more accurate measurements of muscle oxygenation and respond more quickly to changes in exercise intensity (Born et al., 2017; Shibuya et al., 2004).

Near-infrared spectroscopy (NIRS) has established itself as a valid, dependable, and inexpensive wireless instrument in the field of health and physical activity (Farzam et al., 2018; Feldmann et al., 2019; Miranda-Fuentes et al., 2020; Scholkmann & Scherer-Vrana, 2020). Additionally, this technology is able to evaluate the equilibrium between muscle oxygen supply and demand during physical activity in real time (Peikon, 2019). The Moxy monitor is one of several options for measuring local oxygen saturation (SmO2) and total hemoglobin (THb) at the oxygen concentrator in the horizontal position using infrared spectroscopy (NIRS) (Crum et al., 2017). Moxy is also said to be able to measure exercise intensity zones, instead of using speed, strength, or heart rate (HR) which are affected by environmental conditions, fatigue, or mental stress, to guide exercise prescriptions based on the effects of specific mechanical workloads on muscle O2 requirements (Design, 2015).

Research conducted by (Simmons, 2017) on six 21 -year-old students at the University of Carolina, who were trained in endurance through a high-intensity 30-second sprint interval test with a 125% watt VO2 max on the ergometer, showed an inverse relationship between SMO2 and heart rate and VO2 during high intensity. In this study, the test conducted was an endurance test with a multi-step level of 5–1–5 for cyclists, where the endurance test measured the relationship between SMO2 and total hemoglobin in the blood (Thb), which is the novelty of this research

METHODS

This study employed a descriptive technique with a quantitative approach since the research design involved a description of the variables to be researched. The factors examined in this study were total hemoglobin volume and SMO2 levels (THb).

Participants

The single subject design was the technique used in this study. The subject of this study was a cyclist in the city of Bandung who was preparing to compete in regional multi-event competitions, namely a 19-year-old female road bike athlete, with a body weight of 50 kg and a body height of 169 cm.

Instrument and Procedure

The instrument used in this research was Moxy (Muscle Oxygen Monitoring). This tool is used to see how well our muscles use oxygen. Moxy Monitor (Fortiori Design, LLC, Hutschinson, MN, USA) has proven its validity and reliability for use in the sports world. Validity of Moxy to measure SmO2: statistically analyzed and very good results, correlation between trials for all participants (SROC: r = 0.842–0.993, ICC: r = 0.773–0.992, p 0.01) (Jaén-Carrillo et al., 2022). Moxy can be used to measure muscle oxygenation and has a validity of 0.92 compared to direct measurement of venous oxygen saturation and a reliability of r = 0.77 to 0.99 (P 0.01) (Sucharit et al., 2018). In this study, a smartwatch was used as an additional data collection tool. The Elevate Heart Rate sensor on the watch recorded heart rate and how it varied from time to time. This information was used to calculate heart rate variability (HRV). Another tool used in the study was the Ergo-cycle. The Ergo-cycle works in the same way as a bicycle, but the ergo-cycle itself does not move when in use. This tool is useful for racing cyclists when the weather is bad or there is not enough time to ride a regular bike. By using an ergo-cycle, cyclists can experience realistic cycling and the resistance changes depending on how they ride, whether doing structured exercises or cycling in a virtual world.

Procedure

There were several steps taken in this research. After determining the population and sample, the researchers conducted a muscle oxygen saturation test using the Moxy (Muscle Oxygen Monitoring) tool. Moxy has many settings, but researchers set Moxy on the quadriceps based on the cyclist's foot. After the athletes warmed up, the researchers told them to pedal at different levels until they reached exhaustion. Researchers tracked the cyclist cadence (the number of times they had to pedal per minute) to make sure they were working their best. Researchers used the 515 assessment, which means 5 minutes of activity and 1 minute of rest. The athlete pedaled a bicycle starting from binary 1 (level 2, 60 watts) continuously until they reached a level of fatigue, with a record of cadence kept between 40 and 50 smO2 (%). Then, the researcher gave a stop sign to the athlete.

Data Analysis

In this study, the data obtained from the results of measurements using the Moxy monitor were in the form of quantitative data on the result of oxygen saturation in muscle, or SmO2 [%] with total hemoglobin (THb). In addition to the descriptive analysis of performance profiles for cyclists, the relationship or correlation between muscle oxygen saturation (SmO2 [%]) and total hemoglobin (THb) was calculated.

RESULT

Data from the results of the subject's biometric test collected SmO2 levels, which were then processed and analyzed descriptively between road bike athlete during high-intensity training and muscle oxygen saturation. Sample demographic data are shown in Table 1.

Table 1. Physical characteristics of the subjects

SmO2 [%]		**THb[THb]**	
Mean	78.1785364	Mean	11.774756
Standard Deviation	8.70608313	Standard Deviation	0.109231
Sample Variance	75.7958835	Sample Variance	0.011931
Minimum	52.4099998	Minimum	11.529999
Maximum	89.2399978	Maximum	12.010000
Count	82	Count	82
Confidence Level (95.0%)	1.91293625	Confidence Level(95.0%)	0.024000

Based on the demographics of the research subjects in Table 1, the average SmO2 (%) was 78.18 while the average THb was 11.8. The standard deviation of SmO2 was 8.71, and the standard deviation of THb was 0.11.

The data in the graph shown in Figure 1 explain how cycling (power cycling) can affect muscle oxygen saturation levels. The purple line shows how muscle oxygen saturation levels change over time while cycling, while the red line shows the THB between cycling and muscle oxygen saturation levels.

Data description of 515 assessment shows the respondent muscle oxygen saturation while cycling on an ergocycle. In binary 1, round 1 (level 2, 60 watts) with a given time of 5 minutes, they managed to cover a distance of 1.4 km with an average speed of 11.4 rpm, burning 23 calories with an average SmO2 of 74.38% and Hb of 11.78 mg/dL. In binary 1, round 2 (level 2, 60 watts) with a given time of 5 minutes, they managed to cover a distance of 3 km with an average speed of 11.46 rpm, burning 47 calories with an average SmO2 of 74.28% and Hb of 11.79 mg/dl. In binary 2 round 1 (level 4, 100 watts) with a given time of 5 minutes, they managed to cover a distance of 1.5 km with an average speed of 11.8 rpm, burning 36 calories and having an average SmO2 of 85.49 and Hb of 11.85 mg/dl.

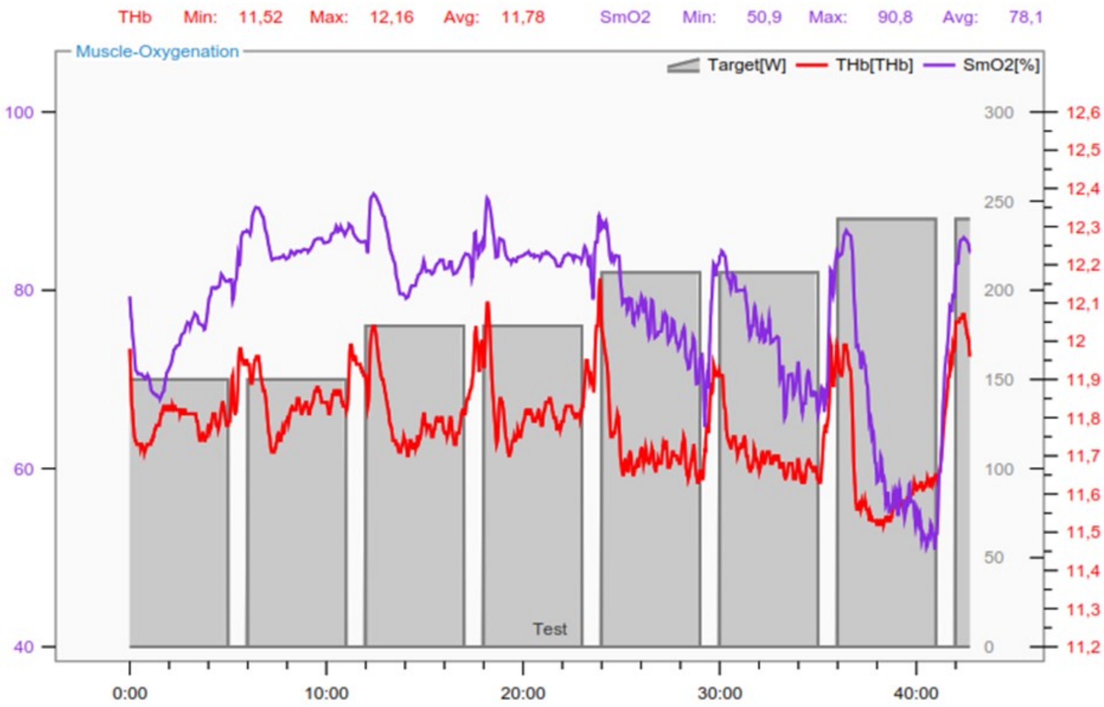

Figure 1. Graph of Respondent SmO2 and THb Profiles

Table 2. Achievement of 515 Smo2 and Watt Tests

Binary	Half	Minute	SmO2	Watt
1	1	5	12,57	60-90
	Rest 1 menit		4,8	
	2	5	4,3	
Rest 1 menit			1,3	0
2	1	5	9,3	100-130
	Rest 1 menit		1,6	
	2	5	5,3	
Rest 1 menit			1,1	0
3	1	5	14,2	140-180
	Rest 1 menit		11,1	
	2	5	14,6	
Rest 1 menit			12.5	0
4	1	5	32	190-230

In binary 2 round 2 (level 4, 100 watts) with a given time of 5 minutes, they managed to cover a distance of 3.1 km with an average speed of 11.64 rpm, burning 71 calories and having an average of 83.97% SmO2 and 11.82 mg Hb/L. In binary 3 round 1 (at level 7, 140 watts) with an allotted time of 5 minutes, they managed to cover a distance of 1.48 km with an average speed of 11.6 rpm, burning 46 calories and having an average of SmO2 of 84.1 and Hb of 11.82 mg/dL. In binary 3 round 2 (level 7, 140 watts) with a given time of 5 minutes, they managed to cover a distance of 2.96 km with an average speed of 11.18 rpm, burning 93 calories and having an average of 79.37% SmO2 and 11.76 mg Hb/l. In binary 4 round 1 (level 9, 180 watts), with a given time of 5 minutes, they managed to cover a distance of 1.33 km with an average speed of 11.18 rpm, burning 51 calories and having an average SmO2 of 75.07 and Hb of 11.71 mg/dl.

Based on Table 3, it can be seen that the test results of all respondents were similar while cycling. The respondent successfully tested up to binary 4 round 1 (level 9, 180 watts). With an average speed of 11.33 rpm, they managed to cover a distance of 14.77 km and burned 367 calories with an average oxygen saturation level of 78.17% and an average hemoglobin of 11.77 mg/dl. The result of the respondent muscle oxygen saturation measurements was in the fairly good category for the female gender because the average results were in the range of 70–80%, not much different from the starting point of the test. The researcher used multiple regression analysis to look at the determinants of road bike athletes. Figure 2 shows that there is a positive correlation between SmO2 and THb, where SmO2 contributes 61%. There is THb.

Table 3. Analysis of Respondent SMO2 Performance

	Half	Heart Rate	RPM	Distance (km)	Calories	SmO^2 (%)	Hb (%)
Respondents	4.1	137.65	11.33	14.77	367	78.17	11.77

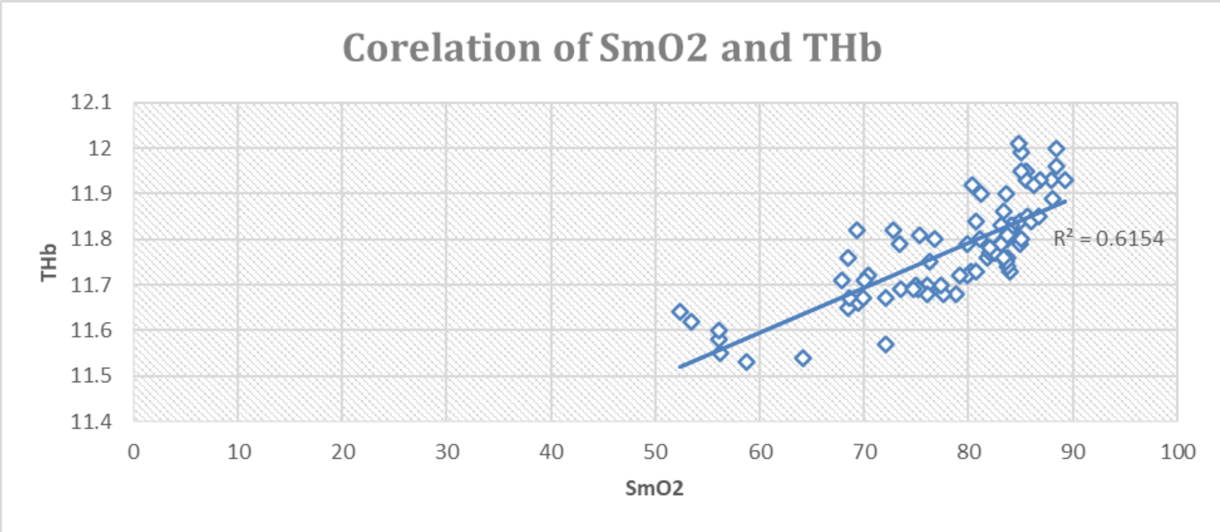

Figure 2. SmO2 and THb Correlation Graph

DISCUSSION

This study, on cyclists, showed a positive correlation between SmO2 and THb, as seen from the moxi monitor measurements shown in Figure 1. In the first binary, the SmO2 value showed an average SmO2 value of 74.38% and Hb 11.78 mg/dl, but in the second binary, there was an increase, namely an average of SmO2 85.49 and Hb 11.85 mg/dl. This shows that the need for SmO2 in the muscles will be in harmony with THb; muscle performance at high intensity requires high oxygen to support the activities carried out. Based on the data presented, it seems interesting to verify the usefulness of SmO2 and THb measurements using the Moxy device for the selection and evaluation of high-intensity aerobic exercise. This is in line with research (Alvares et al., 2020), where there is a strong relationship between NIRS-derived tHb and BF Doppler ultrasound during the exercise phase with a value of r = 0.83.

During exercise, control of blood flow is determined by how well the muscles can use oxygen, which is largely determined by how much oxygen the muscles get and how much oxygen the muscles demand (Casey & Joyner, 2011). VO2max is what determines the diffusion of oxygen in the muscles, where the percentage of SmO2 during exercise can be an index of the capacity of oxygen diffusion in the muscles (Shibuya et al., 2004). During training transitions, the muscles will experience a more marked increase in oxygen availability than oxygen consumption, indicating that the body uses more oxygen to produce energy during the exercise phase (Cerretelli & Di Prampero, 2011; Grassi, 2000). A study conducted by (Rossiter et al., 2001) found that exercise intensity caused Vo2 to increase by about 70% of the maximum for knee extensor exercises.

VO2 Max is important for physical performance and overall health. VO2 Max can be determined by various exercises that activate the body major muscle groups, provided that the intensity and duration of the exercise are sufficient to maximize aerobic energy transfer (Doijad et al., 2013). A study found that cyclists could maintain high levels of oxygen uptake for short periods of time but could also continue to use more oxygen for longer periods of time when they took occasional breaks (ÅStrand et al., 1960). Strength training can improve cycling performance. By increasing the fraction of maximum oxygen uptake (VO2max), it can save energy and still make the bike go faster (Vikmoen et al., 2016). Additionally, increased muscle efficiency can compensate for low V O2max, allowing world-class cyclists to compete at a high level or even innate physiological responses to training and competition, allowing athletes to achieve better results (Santalla et al., 2009).

CONCLUSION

In short, the results of this study indicate that there is a positive correlation between SmO2 and THb, where VO2 max is aligned with THb. High-intensity cycling activities, such as those performed by cyclists, require high levels of oxygen to support exercise performance. This study only carried out on one subject, namely road bike athlete. It is hoped that further research can be carried out on other sports to add to the neurophysiological scientific knowledge in sports.

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CONFLICT OF INTEREST

The authors declared no conflict of interest.

REFERENCES

Alvares, T. S., Oliveira, G. V. de, Soares, R., & Murias, J. M. (2020). Near-infrared spectroscopy-derived total haemoglobin as an indicator of changes in muscle blood flow during exercise-induced hyperaemia. Journal of Sports Sciences, 38(7), 751–758.

ÅStrand, I., ÅStrand, P., Christensen, E. H., & Hedman, R. (1960). Intermittent muscular work. Acta Physiologica Scandinavica, 48(3-4), 448–453.

Born, D.-P., Stöggl, T., Swarén, M., & Björklund, G. (2017). Near-infrared spectroscopy: more accurate than heart rate for monitoring intensity in running in hilly terrain. International Journal of Sports Physiology and Performance, 12(4), 440–447.

Buchheit, M., Abbiss, C. R., Peiffer, J. J., & Laursen, P. B. (2012). Performance and physiological responses during a sprint interval training session: relationships with muscle oxygenation and pulmonary oxygen uptake kinetics. European journal of applied physiology, 112(2), 767-779.

Burke, E. R. (1980). Physiological characteristics of competitive cyclists. The Physician and Sportsmedicine, 8(7), 78–84.

Burke, E. R., Cerny, F., Costill, D., & Fink, W. (1977). Characteristics of skeletal muscle in competitive cyclists. Medicine and Science in Sports, 9(2), 109–112.

Casey, D. P., & Joyner, M. J. (2011). Local control of skeletal muscle blood flow during exercise: influence of available oxygen. Journal of Applied Physiology, 111(6), 1527–1538.

Cerretelli, P., & Di Prampero, P. E. (2011). Gas exchange in exercise. Comprehensive Physiology, 297 –339.

Crum, E. M., O'connor, W. J., Van Loo, L., Valckx, M., & Stannard, S. R. (2017). Validity and reliability of the Moxy oxygen monitor during incremental cycling exercise. European journal of sport science, 17 (8), 1037-1043.

Design, F. (2015). Introduction to Muscle Oxygen Monitoring with Moxy. Muscle Oxygen URL: https://cdn2. hubspot. net/hub/188620/file-433442739-pdf/docs/moxy-ebook-intro-to-muscle-oxygen. pdf [accessed 2018-12-17][WebCite Cache ID 74judgnQa].

Doijad, V. P., Kamble, P., & Surdi, A. D. (2013). Effect of Yogic Exercises on Aerobic Capacity (VO^ sub 2^ max). International journal of physiology, 1(2), 47.

Faria, E. W., Parker, D. L., & Faria, I. E. (2005). The science of cycling: factors affecting performance—part 2. Sports medicine, 35, 313-337.

Farzam, P., Starkweather, Z., & Franceschini, M. A. (2018). Validation of a novel wearable, wireless technology to estimate oxygen levels and lactate threshold power in the exercising muscle. Physiological reports, 6(7), e13664.

Feldmann, A., Schmitz, R., & Erlacher, D. (2019). Near -infrared spectroscopy-derived muscle oxygen saturation on a 0% to 100% scale: reliability and validity of the Moxy Monitor. Journal of biomedical optics, 24(11), 115001-115001.

Gibala, M. J., & McGee, S. L. (2008). Metabolic adaptations to short-term high-intensity interval training: a little pain for a lot of gain?. Exercise and sport sciences reviews, 36(2), 58-63.

Grassi, B. (2000). Skeletal muscle VO~ 2 on-kinetics: set by O~ 2 delivery or by O~ 2 utilization? New insights into an old issue. Medicine and Science in Sports and Exercise, 32(1), 108–116.

Horowitz, J. F., Sidossis, L. S., & Coyle, E. F. (1994). High efficiency of type I muscle fibers improves performance. International journal of sports medicine, 15(03), 152-157.

Jaén-Carrillo, D., Roche-Seruendo, L. E., Cartón-Llorente, A., & García-Pinillos, F. (2022). Agreement between muscle oxygen saturation from two commercially available systems in endurance running: Moxy Monitor versus Humon Hex. Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology, 236(3), 231–237.

Laursen, P. B., Shing, C. M., Peake, J. M., Coombes, J. S., & Jenkins, D. G. (2002). Interval training program optimization in highly trained endurance cyclists. Medicine & Science in Sports & Exercise, 34 (11), 1801-1807.

Miranda-Fuentes, C., Guisado-Requena, I. M., Delgado -Floody, P., Arias-Poblete, L., Pérez-Castilla, A., Jerez-Mayorga, D., & Chirosa-Rios, L. J. (2020). Reliability of low-cost near-infrared spectroscopy in the determination of muscular oxygen saturation and hemoglobin concentration during rest, isometric and dynamic strength activity. International Journal of Environmental Research and Public Health, 17(23), 8824.

Peikon, E. (2019). The future is NIRS: Muscle oxygen saturation as an estimation of the power-duration relationship. Anat. Physiol. Open Access J, 1, 166.

Rossiter, H. B., Ward, S. A., Kowalchuk, J. M., Howe, F. A., Griffiths, J. R., & Whipp, B. J. (2001). Effects of prior exercise on oxygen uptake and phosphocreatine kinetics during high-intensity knee-extension exercise in humans. The Journal of Physiology, 537 (1), 291–303.

Santalla, A., Naranjo, J., & Terrados, N. (2009). Muscle efficiency improves over time in world-class cyclists. Medicine & Science in Sports & Exercise, 41 (5), 1096-1101.

Scholkmann, F., & Scherer-Vrana, A. (2020). Comparison of two NIRS tissue oximeters (moxy and nimo) for non-invasive assessment of muscle oxygenation and perfusion. Oxygen Transport to Tissue XLI, 253 -259.

Shibuya, K. I., Tanaka, J., & Ogaki, T. (2004). Muscle oxygenation kinetics at the onset of exercise do not depend on exercise intensity. European journal of applied physiology, 91, 712-715.

Simmons, J. (2017). The assessment of muscle oxygen saturation in students during maximal VO2 exercise and high intensity intervals.

Sucharit, W., Eungpinichpong, W., & Chatchawan, U. (2018). Immediate effects of isometric muscle contraction on muscle oxygenation and muscle torque. Journal of Medical Technology and Physical Therapy, 30(3), 361–369.

Tanaka, H., Bassett Jr, D. R., Swensen, T. C., & Sampedro, R. M. (1993). Aerobic and anaerobic power characteristics of competitive cyclists in the United States Cycling Federation. International journal of sports medicine, 14(06), 334-338.

Vikmoen, O., Ellefsen, S., Trøen, Ø., Hollan, I., Hanestadhaugen, M., Raastad, T., & Rønnestad, B. R. (2016). Strength training improves cycling performance, fractional utilization of VO2max and cycling economy in female cyclists. Scandinavian Journal of Medicine & Science in Sports, 26(4), 384–396.

Vogt, S., Schumacher, Y. O., Blum, A., Roecker, K., Dickhuth, H. H., Schmid, A., & Heinrich, L. (2007). Cycling power output produced during flat and mountain stages in the Giro d'Italia: a case study. Journal of sports sciences, 25(12), 1299-1305.